TD-05-014

SCRF BCP Facility Mockup: Acid Cooling and Gravity Tank Filling Stages. Process Testing and Safety Features. Results utilizing water.

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Abstract

This note summarizes results of the Cooling and Filling stages of the BCP Process.
All tests were performed with the use of water instead of acids. We measured the temperatures, flows and levels through the designated gauges mounted into the process, heat exchanger, piping and tanks. We also measured the timing for the filling and for the safe recovery of the liquid with the present set-up.
The test of the process indicates that the system is effectively and efficiently cooling the acid mixture to be employed for cavity etching.
Main safety feature of the Process Control have been simulated and cross-compared to TD-04-049. Few possibilities of problem scenario, such as leaks and gauges malfunctioning (inconsistencies,) have been verified, with safe recovery of the system in the events.

Introduction

A simplified schematic of the hydraulic circuit is shown in Figure 1.

The first Cooling Test was made by starting the water chiller, and the Heat Exchanger Pumps 7-1 and 7-2, while re-circulating the water in the barrel B1 through Pump 1 and V13 (Figure 2.)
We utilized about 50 gallons of water and determined time constants. (Figure 3)

A second Cooling Test was made by first cooling the water in the Heat Exchanger, then cooling the water in the Barrel B1. Results are shown in Figure 4.

We also measured the Temperature Change during the filling and the times for the **Filling** and the **Emptying** of the tank T1 through V16 and V13, which is the safe recovery of the acid during the **Filling Stage** of the Process (Figure 5.)

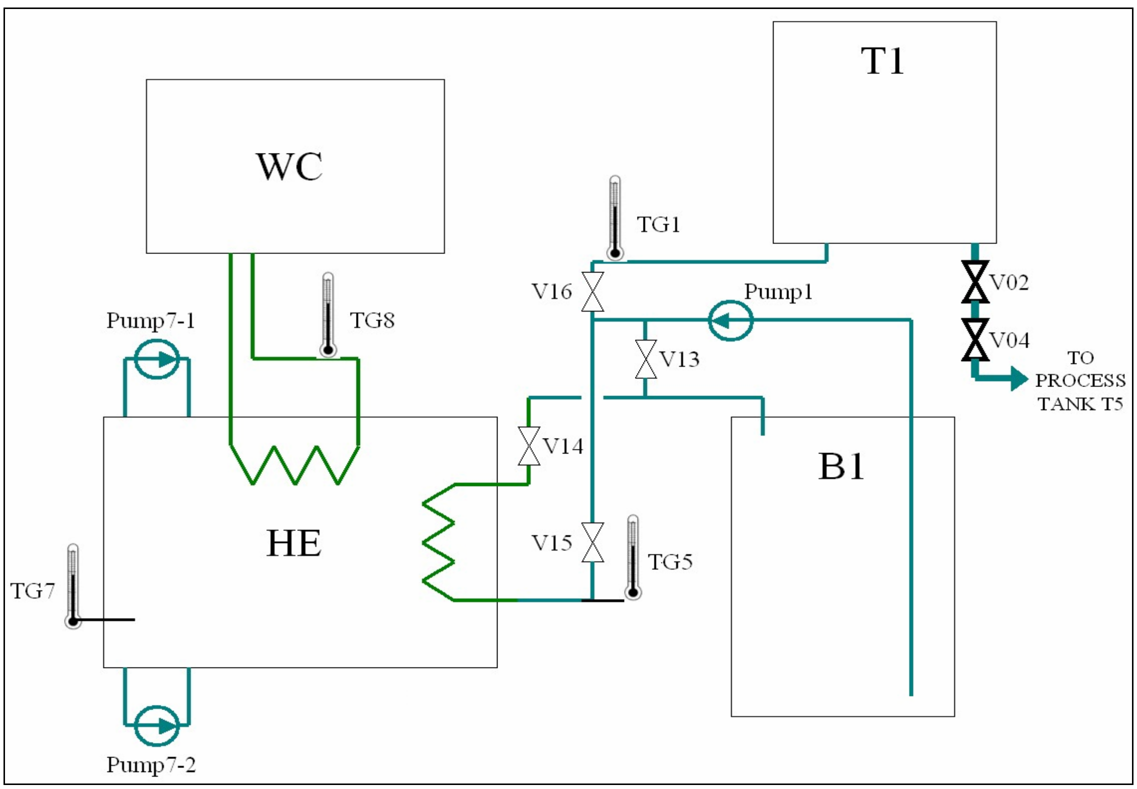

Figure 1: Simplified schematic of the Process-and-Instruments utilized.

Cooling

The cooling process was initiated by running the water chiller and the Pump1 through the by-pass valve V13.
There is a slight increase in the temperature of the water in the barrel, which is likely to be due to friction.
The results are shown in Figure 2. The water chiller is filled with propylene glycol, and set at 5°C.The temperature gauge TG8 detects the temperature along the cooling line.

If approximated with an exponential fit we find the Water Chiller Time Constant of about 12 minutes. It takes approximately 22 minutes for the Water Chiller from room temperature to the steady controlled state of 5°C.

As indicated in the TD-03-055 the Heat Exchanger consists of primary and secondary circuits mounted in tank filled with water. The capacity of the tank is 60 gallons, and the amount of water inside (or the Heat Exchanging Media) tank is about 50 gallons.

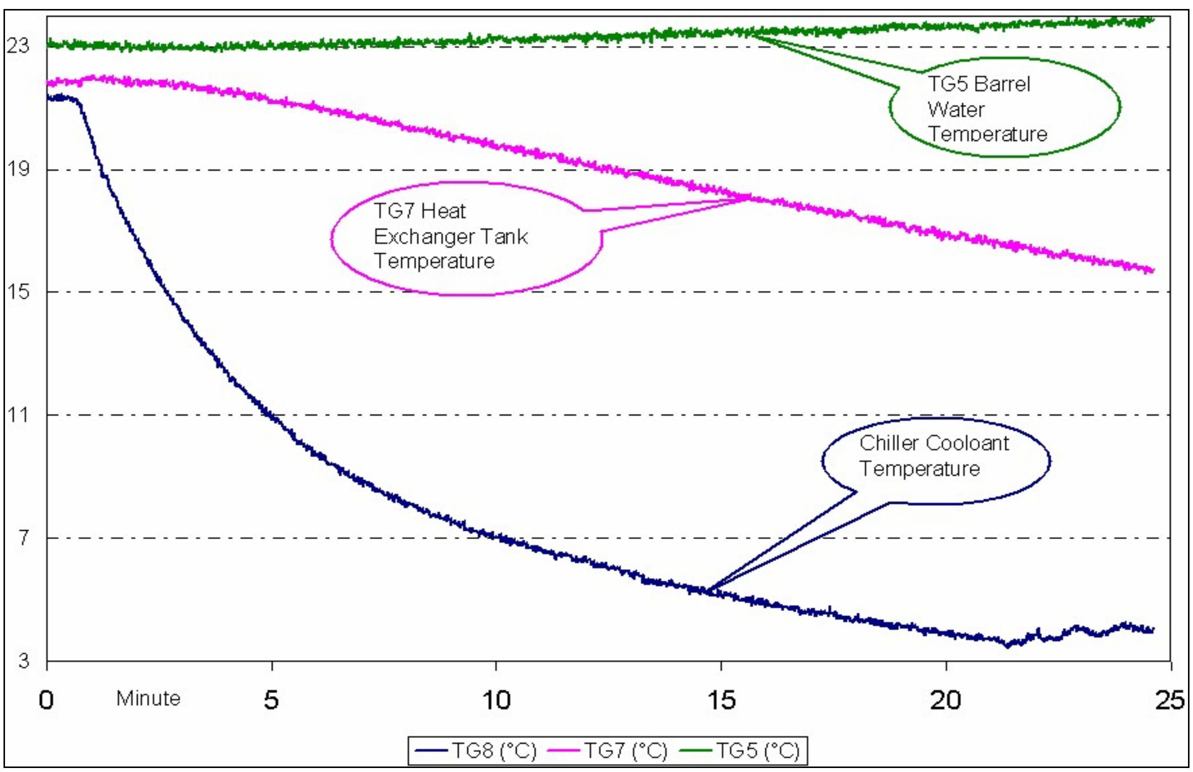

Figure 2: Start of the Chiller and Heat Exchanger Cooling.

The measured flow rate of the glycol circulated through the water chiller is constant at about 4.6 gpm. The two pumps P7-1 and P7-2 circulated the water in the HE tank.
The resulting time constant of the water circulating through the acid tank has been found to be about three hours. Pump 1 maintained the flow rate of the water (Barrel B1 water) at about 3.6 gpm.

The system was able to cool down 50 gallons of water from about 23°C to 11°C in 120 minutes. The result is indicated in Figure 3.

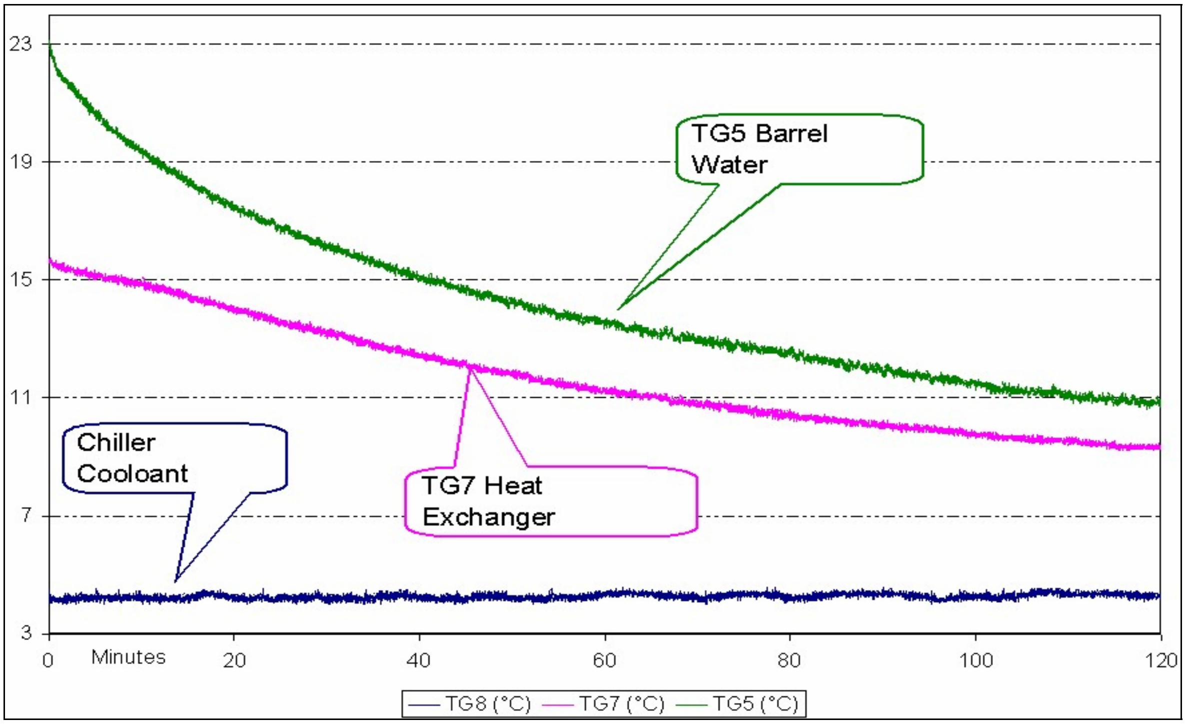

Figure 3: Cooling of 50 gallons of water HE tank temperature starts at 16°C.

We repeated the experiment utilizing the same amount of water, but, in order to limit the acoustic noise due to the Pump1 we first cool down the Heat Exchanger, thereafter run the whole system as prescribed. We obtained comparable results and time constants as indicated in Figure 4.

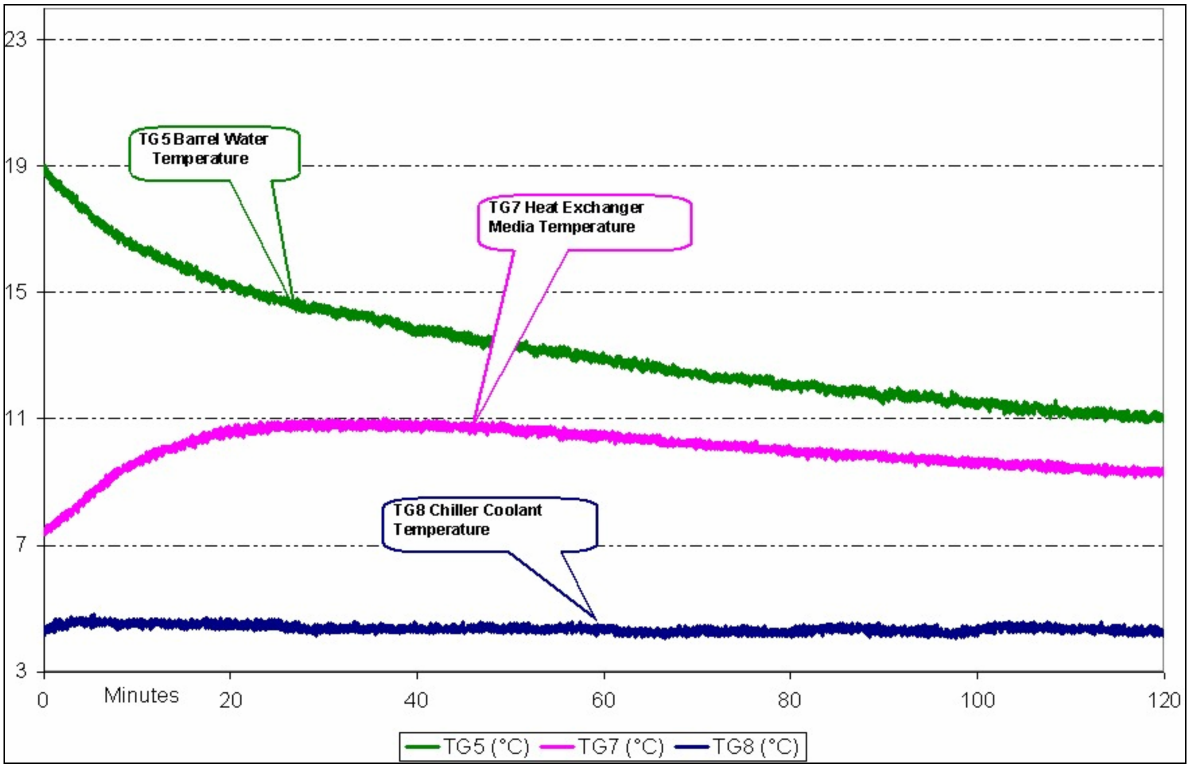

Figure 4: Cooling of 50 gallons of water after HE tank is chilled.

As soon as we start circulating the water contained in the acid barrel B1 the temperature in the tank (TG7) increases. The temperature of the water circulating through the acid tank decreases rapidly with a time constant of about 165 minutes.

That is, after about two hours (120 minutes,) the temperature of the 50 gallons of water contained in B1 has been cooled down to less than 12°C.

Filling

After cooling down the water to about 11°C we filled the Gravity Tank T1.

We measured the temperatures and level utilizing the designated process gauges and the results are in Figure 5. It took about 11 minutes to fill the tank with 36.5 gallons of water. The noise along the level line mid-points is due to a problem with the sensor, which has been replaced after this test.

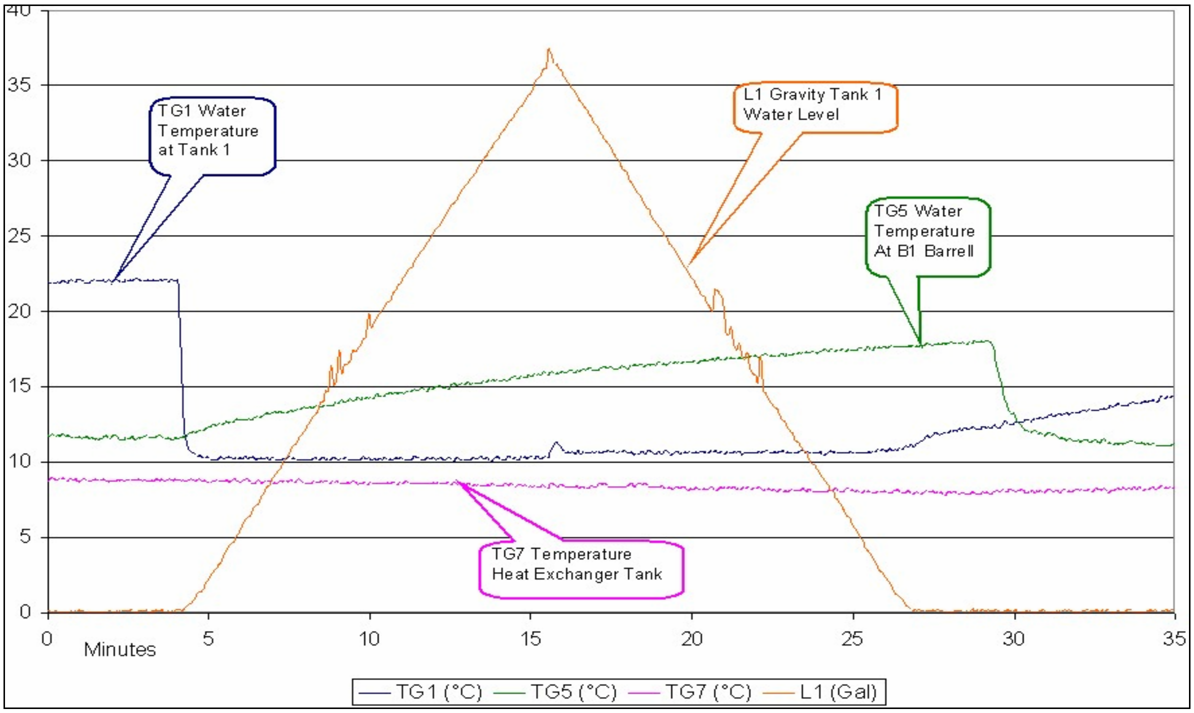

Figure 5: Filling and emptying of the Gravity Tank T1 and temperature check.

It took about the same time to empty the Gravity Tank T1 through the safety by-pass circuit of V16-V13.

The temperature measured through TG5 at the beginning of the filling of the gravity tank was about 11°C. TG1 monitor the temperature while filling the gravity tank and record the sudden drop from room temperature to just over 10°C. There is a slight disagreement between the two gauges. From our first investigation it appears due to the gauge positioning along the process.

After emptying the gravity tank through the same filling line we re-circulated the water through the circuit in order to obtain reading from the previously used gauge TG5 therefore eliminating systematic instrumental error.

The temperature gauge indicated a temperature rise of 0.7°C.

Safety Test and Results

During Cooling

- √ V14 or V15 do not open process stops.
- √ V17 or V18 do not open use V19.
- √ V16 not close stops the process.
- √ V21 or V22 not close stop the process.
- √ V12 leaks stop the process at tank overfull (10% over operator set point).
- √ V36 or V38 not close stop the process.
- √ FM1 not working alarm; possibility of bypass FM1.
- √ FM6 or FM8 malfunctioning stop the process.
- √ TG5 consistencies check fault.
- √ TG6 consistencies check fault alarms.
- √ TG7 consistencies check fault alarms.
- √ TG8 consistencies check fault stops the process.
- √ R6, R7 acid detection or consistencies fault.
- √ L1, L51, L52 alarms.

During Filling

- √ V13, V14 or V15 do not close process stops.
- √ FM1 integrated reading and L1 mismatch stop the process; possibility of bypass. And possibility of proceed versus starting over.
- √ V16 not open stops the process.
- √ V19 do not open use V17 and V18.
- √ V21 or V22 not close stop the process.
- √ V36 or V38 not close stop the process.
- √ TG1 temperatures check inconsistency alarm.
- √ TG6 consistencies check fault alarms.
- √ TG7 consistencies check fault alarms.
- √ TG8 consistencies check fault alarms.
- √ R6, R7 acid detection or consistencies fault Alarm.
- √ L1, L51, L52 alarms.

Conclusions

The system works as per design and we successfully cooled the water to suitable temperature to proceed with the etching of the cavities.
The safety features embedded into the software also performed as per design, and thoroughly specified in the note TD-04-049. These tests provided the support for the required precaution during the final process.

Appendix #1: Gravity Tanks Sizes.

Acid Gravity Tank T1 has an inside diameter of 24" and it is 34" tall from the seam where the cone starts. It has a ¼ " wall and the cone is 6¼" tall.
At its maximum level the capacity is 58.77 gallons considering the 4.08 gallons inside the bottom cone.

Water Gravity Tank T2 has an inside diameter of 22" and it is 44" tall from the seam where the cone starts. It has a $^3/_{16}$" wall and the cone is 5" tall.

At its maximum level the capacity is 65.84 gallons considering the 2.74 gallons inside the bottom cone.

Appendix #2: Tanks Level Transmitters Calibrations.

Calibration of the translating unit to obtain correct readings on the transmitters:

- Unit #1 (T4) → 4-20mA = 0-9" = 229 mm = 0-41.83 gallons = 158.29 liters [rectangle with 26.5" X 40.5" base]
- Unit #2 (T3) → 4-20mA = 0-9" = 229 mm = 0-41.83 gallons = 158.29 liters [rectangle with 26.5" X 40.5" base]
- Unit #3 (T2) → 4-20mA = 0-40" = 0-1,016 mm = 0-65.84 gallons = 249.17 liters [circle with 22" diameter base, not considered the conical bottom]
- Unit #4 (T1) → 4-20mA = 0-30" = 0-762 mm = 0-58.77 gallons = 222.40 liters [circle with 24" diameter base, not considered the conical bottom]

Note: The conical bottom is considered in the programming and correct on the screen readout.

References:

1. **TD-03-055** C. Boffo, I. Terechkine "Water Chiller and Heat Exchanger Test Results".
2. **TD-04-049** C. Boffo "Failure mode analysis".